Application of Technology Demonstrations and Prototyping in Middle Tier Acquisitions

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Abstract

The background for this research is in support of an effort to expand the body of acquisition knowledge within a specific region of program management dealing with the 2016-2018 National Defense Authorization Act Middle Tier Section 804 rapid prototyping and rapid fielding initiative. Specifically, the research aims to improve understanding of the nature and role of technology demonstrations and prototyping as acquisition tools supporting rapid prototyping and fielding.

The research method entails a literature review of classic acquisition, Middle Tier objectives, and how the application of technology demonstrations and prototyping has or has not been applied to previous programs. This review supports a summary analysis intended to assist program managers with a better understanding of the Middle Tier process and how to potentially develop an effective technology demonstration and prototyping strategy. The results are that the services have embraced the Middle Tier authority to quickly field weapon systems given the rapid growth and proliferation of technology along with a continuously evolving threat environment. The research concludes that technology demonstrations and prototyping is generally a value-added endeavor in terms of classic acquisition and with a greater understanding of prototype goals, timing, and integration, program managers will be in a better position to succeed in Middle Tier acquisition. Recommendations include creating a culture of less risk-averse and empowered leadership, aggressively continue the path of Middle Tier acquisition, work with the user community to identify new requirements, encourage stable funding, and develop training for the

Middle Tier acquisition process. Finally, determine how programs initiated via the Middle Tier will effectively transition to programs of record and address the concern of training and sustainment throughout the life cycle of the weapon system.

Introduction

As the Department of Defense (DoD) works to improve the speed of acquiring new weapon systems, language in the Fiscal Year 2016 National Defense Authorization Act (NDAA) and subsequent acts are changing how DoD approaches acquisition. How this new approach nests within the National Defense Strategy, Federal Acquisition Regulation (FAR), DoD Directive 5000.1, "The Defense Acquisition System," DoD Instruction 5000.2, "Operation of the Defense Acquisition System", Army acquisition regulation, and current service guidance on Middle Tier acquisition is worthy of review. With the emphasis of the NDAA guidance from section 804 being rapid prototyping and rapid fielding, an assessment of how the nature and role of Technology Demonstrations and Prototyping (TD&P) as acquisition tools to support this authority is the thrust of this research. The effects of technology and the current threat environment will be assessed in terms of how to best apply TD&P to enable success. A literature review in conjunction with analysis and findings lead to conclusions and recommendations that could potentially assist the acquisition professional with a greater understanding of the legislation as well as supplemental information on how to best apply TD&P. Figure 1 depicts the general approach for this research. A literature review of the NDAA Middle Tier section 804 authority

and related documents, plus a review of prototyping in terms of past and current applicability, provide the information supporting topic analysis, findings, conclusions, and recommendations.

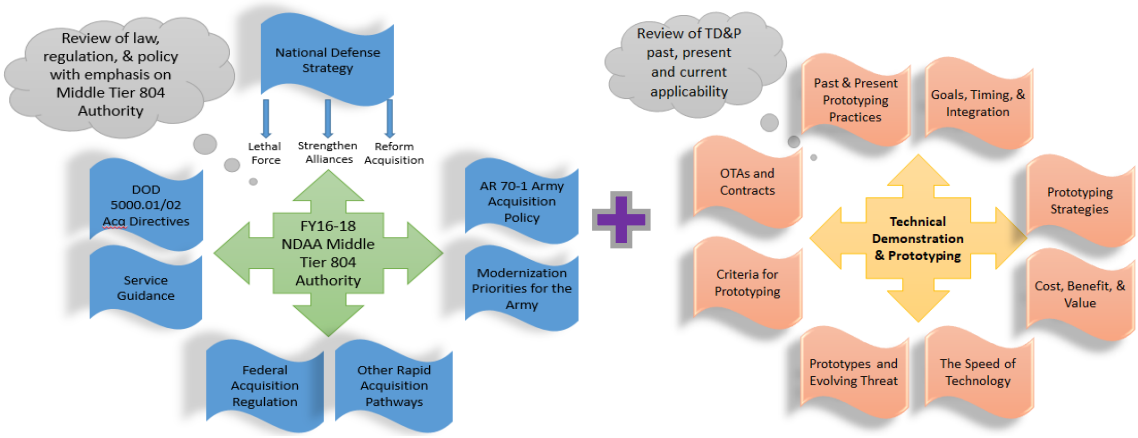


Figure 1. NDAA Middle Tier 804 Acquisition and TD&P Relationship Diagram.

Naturally, this is a complicated problem. The Army promotes a high-level design methodology that encourages the identification of the current state, description of the desired end state, framing of the problem, developing an operational approach, and developing a plan of action. This research works to understand the current leadership intent, acquisition and contracting tools available, and describes a TD&P operational approach or line of effort in terms of implementing the Middle Tier acquisition process. Given the depth and breadth associated with acquiring a weapon system, an effort was made to use a simplified systems engineering model of program management to help narrow the research focus area in terms of inputs, controls, mechanisms, and outputs as depicted in Figure 2.

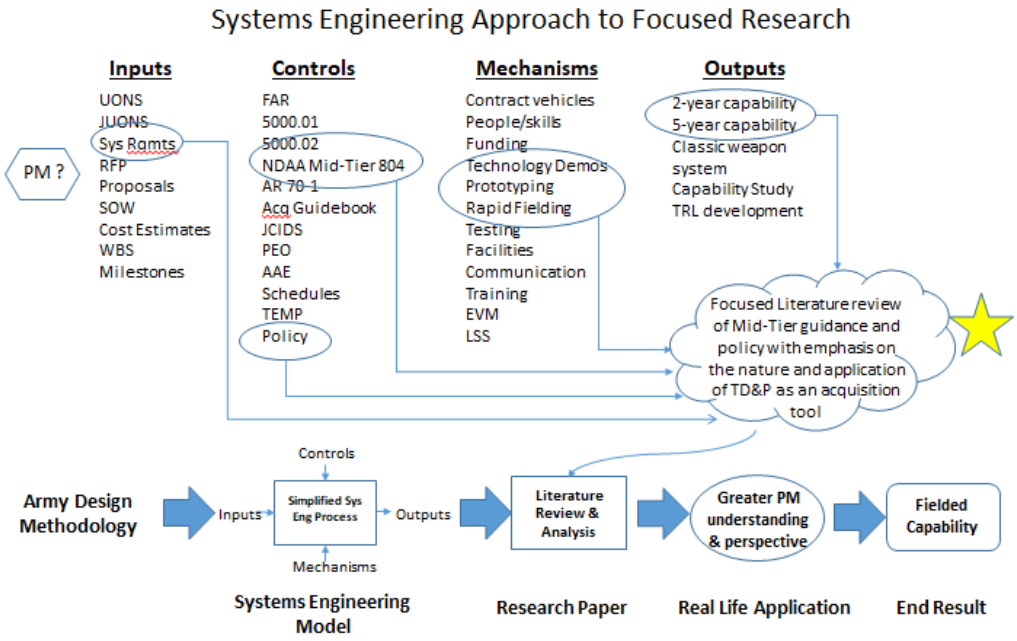


Figure 2. Systems Engineering Approach to Focused Research.

As depicted, this research focuses on the congressional language and policy surrounding Middle Tier acquisition and seeks to improve the program managers' understanding and perspective with respect to the application of TD&P.

The Current Acquisition Environment

The FY16 National Defense Authorization Act (NDAA), and subsequent acts, includes a number of provisions to drive speed, agility, and innovation. These include expanding rapid innovation programs and rapid acquisition authorities. One section that holds particular promise directs the creation of a Middle Tier of acquisition to promote rapid prototyping and rapid fielding acquisition pathways. These programs rapidly field either prototypes or production units and complete

> fielding within five years. There are provisions for funding R&D and rapid prototypes. It empowers senior officials to waive laws and policies that impede certain rapid acquisitions. (Modigliani, 2016, p. 138)

Although these acquisition concepts are not new, there is significant emphasis on speed as opposed to cost given our current operational environment. The pace of technology improvement, adaptive threat, information availability, strategic priorities, and other factors require a faster method of acquiring and fielding systems to meet warfighter needs. Creative use of contracting vehicles, partnerships with industry, acceleration of disruptive innovation technologies, and modernization priorities are driving legislation, oversight requirements and organizational changes. The Army's Futures Command is an example of these changes that represent a paradigm shift in thinking that promotes a more rapid and agile approach to acquisition.

Technology Demonstrations and Prototyping (TD&P)

The world of technology development, technology demonstration, and prototyping can become confusing based on the use of terms, purpose, technology readiness, organizations, funding, direction, and policy. Prototyping is certainly a significant part of technology demonstration but can also serve as a separate activity for reasons not directly related to demonstrating a particular technology such as risk reduction, requirements definition, proof of principle, direct fielding, etc.

Funding is a differentiator related to TD&P. A Budget Activity (BA) is a category within each appropriation and fund that identify the purposes, projects, or types of activities financed by the appropriation or fund (AcqNotes, 2018). There are multiple budget activities for Research,

Development, Test, and Evaluation (RDT&E) accounts that are generally tied to specific Technology Readiness Levels (TRL) and the phase of the program in which the prototype supports (AcqNotes, 2018). Contractor use of Independent Research and Development (IRAD) funds is another aspect that needs consideration.

Technology demonstration and prototyping currently has a significant footprint within DoD. Specifically under the Assistant Secretary of Defense for Research & Engineering is the office of Emerging Capability & Prototyping (EC&P) which oversees the office of Prototyping and Experimentation. EC&P has oversight over the Rapid Reaction Technology office as well as the Joint Capability Technology Demonstration (JCTD) group. The JCTD mission is to:

> Address joint and combatant command warfighting needs through the execution and demonstration of prototypes within two to four years. The program delivers developmental and operational prototypes to affordably operationalize technologies that enable warfighters to explore novel concepts and to facilitate informed transition to formal acquisition programs. (Department of Defense, 2018, p. 1)

"The JCTD Program started as the Advanced Concept Technology Demonstration Program in 1995 and became the JCTD Program in 2006" (Department of Defense, 2018, p. 1). This mission statement is similar to the apparent intent behind NDAA Middle Tier section 804 language concerning rapid prototyping and rapid fielding. Given that the terms technology demonstration and prototyping are so deeply intertwined, for the purposes of this paper the reader is encouraged to accept either of the terms as to generally being "a product (hardware and/or software) that

allows hands-on testing in a realistic environment. In scope and scale, it represents a concept, subsystem, or production article with potential utility" (Drezner, 1992, p. 9).

Problem Statement

Given the current need for modernization with emphasis on speed in the acquisition process, acquisition professionals must interpret the FY16-18 NDAA Middle Tier section 804 acquisition guidance to effectively apply Technology Demonstrations and Prototyping (TD&P) as part of the rapid prototyping and rapid fielding initiatives to meet the constantly evolving operational warfighting needs.

The Research Question

How do program managers effectively apply technology demonstrations and prototyping as part of the Middle Tier section 804 acquisition process such that decisions can be made regarding the goals, timing, and integration of these tools that maximize the potential for a successful acquisition and fielding in terms of cost, schedule, and performance?

Research Methodology

The problem statement and research question delve into Department of Defense's (DoD's) acquisition strategy and guidance. Review of law, regulation, and policy with emphasis on Middle Tier 804 authority together with an analysis of effectively applying TD&P is the heart of this research effort. As such, the concepts of acquisition authority of any kind combined with the application of technology demonstrations and prototyping is part of a very extensive topic. There

is an enormous amount of information available for review. The intent of this research is twofold. First, to understand the current rapid acquisition policy, guidance, law, and regulation with strong emphasis on the NDAA section 804 Middle Tier acquisition approach. Second, to study past and present use of technology demonstrations and prototyping to better understand and apply these tools. Given that DoD is laden with law, regulation, policy, executive guidance, priorities and the strong desire to move faster, a focused literature review of these topics is of potential interest and use to today's program managers involved in rapid acquisition. This research works to provide a summary analysis of that body of knowledge to develop findings, draw conclusions, and make recommendations for acquisition professionals to learn from as they advance their programs to meet warfighter needs.

Literature Review and Approach

The literature review examines current strategies and policies, past acquisition programs, and the current state of Middle Tier acquisition within the military services. Coupled with relevant prototyping and fielding topics, a picture of the benefits and barriers to timely and or rapid acquisition begin to emerge. Strategic documents, directives and regulations, current policy memoranda, and relevant publications from DoD and government think tanks form the basis of the literature review.

Limitations and Recommended Areas of Additional Research

The paper's main limitation centered on time availability to devote to the research. As such, the scope is limited to a literature review and analysis of a very narrow aspect of the DoD

acquisition process. The scope is limited to the Middle Tier 804 process with TD&P as enabling tools. These are broad subjects with much written about them and this research included only parts of the available information on these subjects. One possible area for a follow on study would be to identify programs over the next five years that are actively implementing the Middle Tier rapid prototyping and rapid fielding approach to qualitatively, and possibly quantitatively, evaluate the levels of success and report lessons learned in terms of the initial plans and intent of this acquisition methodology. Metrics on the system type, complexity, schedule, cost, and related prototype details with respect to quantity, fidelity, timing, technical risk, performance characteristics, and overall usefulness could help drive and potentially improve future rapid acquisition policy and implementation. Given the number of multidimensional aspects of prototyping/program characteristics, future data assessments along with weighting factors should help give this additional research more meaning to assist and guide program managers and policymakers.

Literature Review

The purpose of this review is to research relevant literature associated with general acquisition law, regulation, and policy with emphasis on the Middle Tier 804 acquisition provision. Emphasis is placed on the potential value of technology demonstration and prototyping as one of several streamlined acquisition initiatives in support of national defense and modernization priorities. The research evaluated research papers, articles, pamphlets, regulations, briefings, memoranda, web sites, and other literature. The following section provides a brief

synopsis of 23 pertinent subject areas supported by 35 source documents reviewed in relation to this study.

The National Defense Strategy

The 2018 National Defense Strategy (NDS) is an overarching document that augments the National Security Strategy. It describes the DoDs enduring mission in an "increasingly complex security environment defined by rapid technological change, challenges from adversaries in every operating domain, and the impact on current readiness" (Department of Defense, 2018, p. 1). The strategy describes the "reemergence of long-term, strategic competition" by nations such as China and Russia as well as the destabilizing effects of "rogue regimes such as North Korea and Iran" (Department of Defense, 2018, p. 2). The NDS outlines a variety of defense objectives. It has three priorities that focus on "building a more lethal force, strengthening alliances and attracting new partners, and reforming the department for greater performance and affordability" (Department of Defense, 2018, pp. 5-10).

Three Lines of Effort

The basic elements of the NDS were reiterated on October 12, 2017, in a letter to DoD personnel by Secretary of Defense James Mattis where he clearly expressed the need for a sense of urgency by stating that "I expect you to pursue actively these three lines of effort," Mattis went on to write "Set disciplined goals, collaborate across components, and model appropriate ethical behavior". (Pellerin, 2017)

Federal Acquisition Regulation

> The Federal Acquisition Regulations System is established for the codification and publication of uniform policies and procedures for acquisition by all executive agencies. The Federal Acquisition Regulations System consists of the Federal Acquisition Regulation (FAR), which is the primary document, and agency acquisition regulations that implement or supplement the FAR. The FAR System does not include internal agency guidance of the type described in 1.301(a)(2). (United States Government, 2019, p. 31)

Acquisition Reform in the FY2016-FY2018 National Defense Authorization Acts (NDAAs)

> Congress has been particularly active in legislating acquisition reform over the last three years with focus provisions of the legislation being faster and more efficient acquisitions, major defense acquisition programs, the acquisition workforce, commercial items, Other Transaction Authority (OTA), and contract types. (Schwartz & Peters, 2018, p. 1)

In an effort to be more timely and efficient, one particular provision in section 804 "required DoD to develop guidance for rapidly acquiring middle tier programs (intended to be completed in two to five years), to include rapid prototyping and rapid fielding" (Schwartz & Peters, 2018, p. 2). The implications and application of this section of the NDAA are central to this research effort. A point of significance is that "programs subject to the (804) guidance shall not be subject to the Joint Capabilities Integration and Development (JCIDS) System Manual and DoD 5000.01,

except to the extent specifically provided in the guidance" (United States Government, 2015, p. 159).

NDAA to Shake Up DoD Acquisition

A 2015 article on Federal News Network.com discusses U.S. Senate amendments to the 2016 NDAA that shift some responsibilities from the Office of the Secretary of Defense (OSD) to the military's service chiefs and "decentralize to the maximum extent practicable decision-making authority to the services" (Serbu, 2015, p. 2).

> Besides devolving responsibilities to the military's services, the bill's other acquisition provisions include measures designed to encourage more use of commercial technologies in DoD. The committee language says that was the point of several mid-1990s reforms such as the Clinger-Cohen Act, the Federal Acquisition Streamlining Act and the use of Other Transaction Authority. However, the committee asserts that the use of those laws has "atrophied" over the years and that DoD has built new barriers to commercial technology. (Serbu, 2015, p. 2)

The article goes on to discuss how:

> The bill would create what its authors call a "middle tier" of acquisition to fill the gap between traditional programs, which take years to field, and "rapid" acquisitions, which are supposed to take only months. The middle tier would be designed for programs that could meet emerging military needs within five years

> through rapid prototyping or that could use already-proven technologies to quickly upgrade systems. (Serbu, 2015, p. 2)

Middle Tier of Acquisition (Rapid Prototyping/Rapid Fielding) Interim Authority and Guidance

> In an effort to streamline rapid prototyping and fielding, Under Secretary of Defense for Acquisition and Sustainment Ellen Lord released a memo April 16, 2018, providing interim guidance on one of the most foundational changes to Defense acquisition in years -- Middle Tier Acquisition. (Defense Acquisition University Public Affairs, 2018, p. 1)

This memorandum describes the 804 provisions of NDAA for Fiscal Year 2016 (Public Law 114-92), providing the authority to implement Section 804 on an interim basis until September 30, 2019, and gives implementation guidance. This interim guidance asks/directs services to "initiate Middle Tier of Acquisition Rapid Prototyping programs with the objective to field a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within five years" (Lord, 2018, pp. 1-2). Additional implementation guidance for rapid prototyping and rapid fielding, funding, data, education, training, and related changes to existing policy are also part of this memorandum.

Middle Tier Acquisition and Other Rapid Acquisition Pathways

Section 804 Middle Tier of Acquisition is all about rapid acquisition pathways made available by recent National Defense Authorization Acts. Although section 804 deals with rapid

prototyping and rapid fielding, it is only one of several rapid acquisition initiatives existing within the DoD. Other methods include NDAA Section 806 – "Development, Prototyping, and Deployment of Weapon System Components, DODI 5000.02 Tailoring and Accelerated Acquisition Model 4, DODI 5000.02 Enclosure 13 Urgent Capability Acquisition, FAR Direction, and Service Implementation Direction" (Modigliani, Chang, & Ward, 2018, p. 2). Although other rapid approaches are available via NDAA direction, the focus of this research is on section 804. As such, there are other avenues currently available to program managers concerning DoD rapid acquisitions.

Service Guidance on Middle Tier Acquisition

On April 24, 2018, The Assistant Secretary of the Navy (Research, Development, and Acquisition), James Geurts, issued a detailed memorandum providing Middle Tier Acquisition guidance (Geurts, 2018). On June 13, 2018, William B. Roper, Jr. Assistant Secretary of the Air Force (Acquisition, Technology & Logistics) also issued a guidance memorandum for rapid acquisition activities (Roper, 2018). Finally, on September 25, 2018, the Assistant Secretary of the Army (Acquisition, Logistics, and Technology), Bruce D. Jette, issued a Middle Tier Acquisition policy memorandum (Jette, 2018). These documents provide overarching service guidance regarding section 804 implementation, roles and responsibilities, program initiation and transition to acquisition programs. The documents go on to address rapid prototyping, rapid fielding, testing, merit-based selection framework, and other details regarding application of NDAA section 804 authorities.

The Defense Acquisition System, DODD 5000.01

The Department of Defense Directive (DODD) 5000.01 applies to all acquisition programs throughout DoD. The Defense Acquisition System defined as "the management process by which the Department of Defense provides effective, affordable, and timely systems to the users" (Department of Defense, 2007, p. 2). DODD 5000.01 defines the duties and responsibilities of the Milestone Decision Authority (MDA), and the Program Manager (PM). The directive lists policies that address flexibility, responsiveness, innovation, discipline, and streamlined and effective management. (Department of Defense, 2007) DODD 5000.01 addresses responsiveness.

> Advanced technology shall be integrated into producible systems and deployed in the shortest time practicable. Approved, time-phased capability needs matched with available technology and resources enable evolutionary acquisition strategies. Evolutionary acquisition strategies are the preferred approach to satisfying operational needs. Incremental development is the preferred process for executing such strategies. (Department of Defense, 2007, p. 3)

This directive goes on to state in Enclosure 1 that "Competition shall provide major incentives to industry and Government organizations to innovate, reduce cost, and increase quality. Acquisition managers shall take all necessary actions to promote a competitive environment" (Department of Defense, 2007, p. 5).

Operation of the Defense Acquisition System, DODI 5000.02

This Department of Defense Instruction (DODI 5000.02) provides the framework, procedures, and standards for the Defense Acquisition System dated August 10, 2017:

> The instruction provides the policies and principles that govern the defense acquisition system and forms the foundation for all DoD programs that include weapon systems, services, and Automated Information Systems (AIS). DODI 5000.02 establishes a Management Framework for translating user needs and technology opportunities into stable, affordable and well-managed acquisition programs. The instruction also identifies the specific statutory and regulatory reports and other information requirements for each Milestone and Decision Point. The instruction is published by the Under Secretary of Defense (USD) for Acquisition and Logistics (A&L). (Manning, 2018, p. 1)

U.S. Army Acquisition Policy, AR 70-1

This regulation is the Army's implementation of *The Defense Acquisition System, DODD 5000.01* and the *Operation of the Defense Acquisition System, DODI 5000.02*. "AR 70-1 governs research, development, acquisition, and life cycle management of Army materiel solutions to satisfy approved Army requirements for warfighting capabilities" (U.S. Army, 2018, p. i). This major revision, dated 10 August 2018 adds policy on rapid fielding of capabilities (chap 13) in support of Urgent Capability Acquisition. DODI 5000.02 details prototyping and waiver requirements, and the notifications required by statute. Army MDAs may approve prototyping

critical technologies, sub-components, components, or subsystems in the TMRR phase before Milestone B or waive the competitive prototyping requirement (U.S. Army, 2018).

Modernization Priorities for the United States Army

Streamlined acquisition and prototyping are part of the modernization strategy. “To be successful, we must turn ideas into actions through continuous experimenting and prototyping, improving acquisition business processes, pursuing appropriate commercial/off-the-shelf options, and improving training” (Milley, 2017, p. 1). “It will directly incorporate requirements from the warfighter into the acquisitions process and allow us to prototype concepts” (Milley, 2017, p. 2). “We will reduce the time to deliver for the new systems we need to regain our competitive advantage before the next first battle” (Milley, 2017, p. 2).

The Use of Prototypes in Weapon System Development

This research provides a historical perspective on prototyping. In 1981, the Rand Corporation prepared a report for the United States Air Force to “examine the role of prototypes in the contemporary environment of weapon system acquisition” (Smith, Barbour, McNaugher, Rich, & Stanley, 1981). This analysis was:

> Based on case studies of systems developed during the late 1940s and the 1950s, when prototyping was a common practice. As acquisition strategies evolved during the succeeding years, the continuing validity of the earlier results became questionable, but there was little modern evidence to draw upon until the early 1970s, when several new development programs included a prototype phase. This

> study examines the role of prototypes in the contemporary environment of weapon system acquisition. The research draws on case studies of four systems (two Air Force airplanes and two Army helicopters) that were developed in the early 1970s and that used prototypes in varying ways. The research objective is to sharpen the understanding of the various advantages and disadvantages of prototyping and the conditions under which its use may be advantageous. (Smith et al., 1981)

The Nature and Role of Prototyping in Weapon System Development

Historically the DoD has consistently expressed interest in the value of prototyping. A report titled *The Nature and Role of Prototyping in Weapon System Development* prepared for the Office of the Under Secretary of Defense (Acquisition) in 1992 states:

> Research effort focused on identifying and analyzing the range of system and subsystem prototyping strategies available to the Department of Defense (DoD) and appropriate to the acquisition environment of the late 1980s and 1990s. As part of that effort, this report examines the general nature of prototyping, develops an analytical framework for thinking about prototyping in weapon system development, and analyzes past and present prototyping programs within this framework. (Drezner, 1992, p. iii)

From Marginal Adjustment to Meaningful Change: Rethinking Weapon System Acquisition

In 2010, the Rand Corporation conducted research sponsored by the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD (AT&L)). This effort:

> Led to six occasional papers on topics that are likely to be of critical importance to DoD leadership: competition, novel systems, prototyping, risk management, organizational and management issues, and the acquisition workforce. These papers build on RAND staff's deep experience in acquisition management issues to provide innovative ideas and suggestions to revitalize defense acquisitions. (Birkler, Arena, Blickstein, Drezner, Gates, Huang, Murphy, Nemfakos, & Woodward, 2010)

Prototyping Defense Systems

As the DoD continued to assess the nature and overall value of prototyping in the early nineties, the Office of the Under Secretary of Defense (Acquisition) charged the Institute for Defense Analyses of Alexandria, VA in 1992 to investigate and assess this topic. As such, the institute determined that:

> Technical risk is a major cause of cost growth and schedule slip, and this paper investigates whether prototyping improves cost and schedule outcomes. The paper develops a framework for examining the level and purpose of prototypes. It examines cost growth and schedule slip for non-prototyped programs and

> prototypes of various levels and purposes. (Tyson, Nelson, Gogerty, Harmon, & Salerno, 1991)

This paper is useful with suggested broad guidelines and rules of thumb for prototyping during that timeframe and addressed the impact of threats to national security and prototyping on the industrial base. (Tyson et al., 1991) The analysis and recommendation sections of this research consider these assessments.

Prototyping Has Benefited Acquisition Programs, but More Can Be Done to Support Innovation Initiatives

In 2017, the Government Accountability Office (GAO) reported to Congressional committees on how "prototyping can help reduce risk in weapon system acquisition programs by improving understanding of technologies, requirements, and proposed solutions." (United States Government Accountability Office, 2017, p. 1) This report accompanied the National Defense Authorization Act (NDAA) for Fiscal Year 2016 and describes how DoD's research and development funds are used and whether this approach effectively supports activities such as prototyping. This report assesses "(1) how DoD has used prototyping prior to system development on major defense acquisition programs, and (2) what steps DoD has taken to increase innovation through prototyping activities conducted outside of Major Defense Acquisition Programs (MDAP)" (United States Government Accountability Office, 2017, p. 1). The GAO report reviewed 22 MDAPs across DoD since 2009 through 2016 where 17 used some form of prototyping during technology development and five did not prototype. The report provides a detailed assessment and recommended strategies for prototype implementation in

terms of risk reduction, private sector innovation, budget planning, business case analysis, application timeframes, competitive prototyping, incremental improvements, and disruptive innovation. The GAO report provides information and insight for the findings and analysis portions of this research paper and provides relevant data supporting the recommendations and conclusion sections (United States Government Accountability Office, 2017).

Competitive Prototyping

Competitive prototyping is a popular topic given that "In several recent acquisition reform initiatives, the U.S. government encouraged or required competitive prototyping as a tool to assess technology maturity and reduce program risk" (Mitre Corporation, 2018, p. 2). As such, the Mitre Corporation incorporated a section within their Systems Engineering Guide devoted to competitive prototyping that addresses general use, best practices, and lessons learned. The GAO's 2017 report to congressional committees on prototyping contains a significant amount of analysis on competitive prototyping that includes the relative cost of prototyping efforts in comparison to noncompetitive programs (United States Government Accountability Office, 2017). The Defense Acquisition Research Journal posted an article on suggesting a better approach to competitive prototyping where they discuss the nature and use of prototyping where "the debate is over how competition should be approached so that it provides enough value to warrant its costs" (Borowski, 2015, p. 1). The Borowski (2015) article goes on to discuss some of the challenges related to competition with emphasis on budgetary pressures.

Potential Adverse Effects of Competitive Prototyping Validation

LTC James A. Evans developed this analysis for the Defense Systems Management College's Program Management Course. The purpose of this study was "to determine if competitive prototype development under cost-plus incentive fee contracts might also include increased cost growth and gold plating potential" (Evans, 1974, p. 2). Specifically, the paper assesses if "in competitive prototype validation the contractor is motivated to disregard target cost to get increased performance believing that such a strategy will win the full-scale development contract". (Evans, 1974, p. 2) Evans assesses "if contractors are motivated to disregard target cost, what can the PM office do to minimize the effects" (Evans, 1974, p. 2). Cost is one of many dilemmas relating to competitive prototyping assessed as part of this effort with current assessments by the Mitre Corporation, Rand Corporation, GAO, and other sources contributing to the general analysis, findings, recommendations, and conclusions of this paper.

Applicability of Usability Evaluation Techniques to Aviation Systems

Evaluating system designs from a variety of perspectives begins very early in the life of a program. Usability of aviation systems is the prime variable that the study by Clamann and Kaber (2004) addresses with emphasis on how usability directly affects cost, schedule, safety, technology, and effectiveness. The authors believe:

> A usability domain expert should perform a cold heuristic evaluation early in the design process during the task-function analysis step before any prototypes are developed. This can expose flaws in the design before the design team begins

> drafting the first prototype, resulting in less time lost due to revisions. (Clamann & Kaber, 2004)

Clamann and Kaber (2004) state that "Another additional heuristic evaluation could be conducted each time a prototype is developed for review by the design team to validate the design" (Clamann & Kaber, 2004, p. 22). The analysis portion of this paper will assess these considerations, as the considerations may be significant during a rapid prototyping and rapid fielding environment.

Prototyping - Increasing the Pace of Innovation

The speed of technology development and easy access to information has been an increasing concern to DoD for some time. An article from Defense AT&L Magazine highlights, along with many other evaluated sources, these aspects. Specifically, the discussion revolves around how:

> A concerted focus on prototyping activities directed toward developing those critical enablers to innovation—open architectures, modular and reusable designs, and the early application of a rapid, iterative development cycle methodology—can help the DoD build the portfolio of agile and flexible systems it needs to outpace any adversary. (Hencke, 2014, p. 14)

On Prototyping – Lessons from Rand Research

A paper prepared for the Office of the Secretary of Defense by the Rand Corporation provides analysis in regards to how "Acquisition policy and practice reflect the recurring theme

that prototyping as part of weapon system development can improve program outcomes" (Drezner & Huang, 2010, p. 3). The article offers suggestions on important topics for leadership relating to:

> The use of competition, development of novel systems, prototyping, risk management, organizational and management issues, and the acquisition workforce. The papers are designed to inform new initiatives for markedly improving the cost, timeliness, and innovativeness of weapons systems that the Department of Defense (DoD) intends to acquire. (Drezner & Huang, 2010, p. 1)

Assessing the Use of "Other Transactions" Authority for Prototype Projects

> To speed weapon system acquisition within the DoD, Congress has been active in providing legislative guidance in a variety of legislative actions.
>
> In 1994, Congress authorized use of Other Transactions (OT) for the development of prototypes "directly relevant to weapons or weapon systems." Under this authority, projects are not required to comply with procurement-specific laws and regulations. In effect, OT authority provides a blanket waiver of laws such as the Truth in Negotiations Act and the Competition in Contracting Act, and regulations such as the Federal Acquisition Regulation (FAR), and the defense supplement to the FAR. (Smith, Drezner, & Lachow, 2002, p. vii)

The Rand Corporation conducted research for the Director of Defense Procurement in the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD [AT&L]). The purpose of the research was to determine if the "benefits expected from relaxing the process

controls justify the possible costs that might be incurred" (Smith et al., 2002, p. vii) There was focus on the general characteristics of typical OT agreements, benefits, disadvantages, and net effects. This article, among others on the topic of OT agreements, supports the analysis and findings sections of this research project.

Analysis & Findings

Classic Acquisition

Typical acquisition programs execute via guidance found in Title 10 U.S. Code under service, supply, and procurement with execution in accordance with the DoD Instruction 5000.02 "Operation of the Defense Acquisition System". Programs have an Acquisition category (ACAT) and Milestone Decision Authorities (MDAs) driven by the cost and nature of the acquisition. Figure 3 depicts the current standard elements of the Defense Acquisition System such as decision points, milestones, and phases.

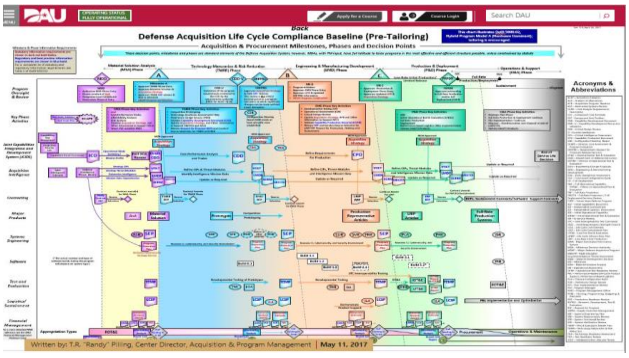


Figure 3. Defense Acquisition Lifecycle Compliance Baseline. Pilling, T. R. (2017, May 11). Program Management. Retrieved December 28, 2018, from https://www.dau.mil/training/career-development/program-management/blog/Update-DoD-Acquisition-Life-Cycle-Wall-Chart

Without delving into the details of this process, Figure 3 provides an overall idea of the complexity of classic acquisition. Albeit somewhat simplified from years past and tailorable to a certain extent, the current process has evolved as a result of lessons learned that created various laws, regulations, policies, and procedures. Congress is concerned that Major Defense Acquisition Programs (MDAP), as well as smaller acquisition efforts, need streamlined processes with

reduced paperwork. (Serbu, 2015, p. 1). In regards to the 2016 NDAA, Sen. John McCain (R-Ariz.), the Chairman of the Armed Services Committee, stated that he views the system to be broken with the current oversight and accountability structure as unsound, evidenced by repeated cost and schedule overruns. “It takes too long, costs too much and wastes billions of dollars, often on weapons systems that never become operational and with no one ever being held accountable,” he said. “That’s why this legislation includes the most sweeping acquisition reforms in a generation” (McCain, 2015 as cited in Serbu, 2015, p. 2).

Middle Tier Acquisition

With the passage of the FY2016-FY2018 National Defense Authorization Acts and service guidance on implementation, the use of Middle Tier acquisition is another tool available to program managers. The Under Secretary of Defense’s (Acquisition and Sustainment) Middle Tier of Acquisition (Rapid Prototyping/Rapid Fielding) Interim Authority and Guidance provides authority to the Department of Defense (DoD) to:

> Rapidly prototype and/or rapidly field capabilities under a new pathway, distinct from the traditional acquisition system. Under the Middle Tier of acquisition, programs subject to the guidance shall not be subject to the Joint Capabilities Integration Development System (JCIDS) manual and DoD Directive 5000.01, "The Defense Acquisition System," except to the extent specifically provided in the implementing guidance. (Lord, 2018, p. 1)

Specific implementation goes on to state:

> Subject to the provisions of Section 804, organizations utilizing this authority are authorized to initiate Middle Tier of Acquisition Rapid Prototyping programs with the objective to field a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within five years of the development of an approved requirement, and Middle Tier of Acquisition Rapid Fielding programs that shall begin production within six months and complete fielding within five years of an approved requirement. The DoD Components will determine what constitutes an approved requirement or may leverage an existing requirement). (Lord, 2018, p. 2)

In a Sept. 25, 2018 memo, Army acquisition executive Dr. Bruce Jette outlines the service's own Middle Tier Acquisition (MTA) guidance on using the rapid prototyping and fielding authority known as section 804. This memo discusses the intent of the section 804 and goes on to clarify that there are no dollar thresholds or Acquisition Categories (ACAT) thresholds associated with the MTA authority and that approved MTA efforts are not considered Major Defense Acquisition Programs (MDAP) regardless of dollar value. Without being held to the provisions of the JCIDS or DoD 5000 series the Army provides detailed implementation guidance for rapid prototyping and rapid fielding in terms of initiation, funding, responsibilities, decision authorities, and how to transition to procurement and fielding.

The memo clarifies two distinct pathways for implementing MTA:

(1) Rapid Prototyping - Use innovative technology to rapidly develop fieldable prototypes to demonstrate or evaluate new capabilities, meeting emerging military needs. The objectives are:

- Field a prototype and demonstrate in an operational environment

- Provide for residual operational capability within 5 years of an approved requirement

(2) Rapid Fielding - Use proven technologies to field production quantities of new or upgraded systems with minimal development required. The objectives are:

- Begin production within 6 months

- Complete fielding within 5 years of an approved requirement

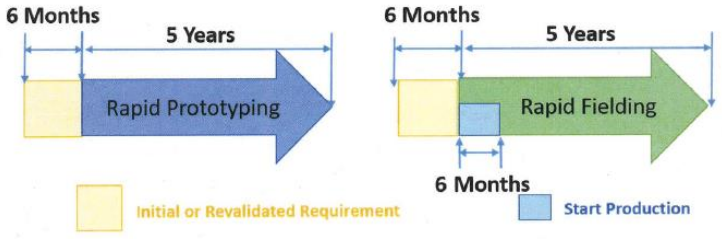


Figure 4. Rapid Prototyping and Rapid Fielding Timelines. Jette, B. D. (2018, September 25). Office of the Assistant Secretary of the Army (Acquisition, Logistics, Training) Middle-Tier Acquisition Policy [Letter to Army Distribution]. 103 Army Pentagon, Washington, DC.

The MTA guidance goes on to provide rapid prototyping and rapid fielding timelines as shown in Figure 4 as well as a more detailed notional prototyping timeline as shown in Figure 5.

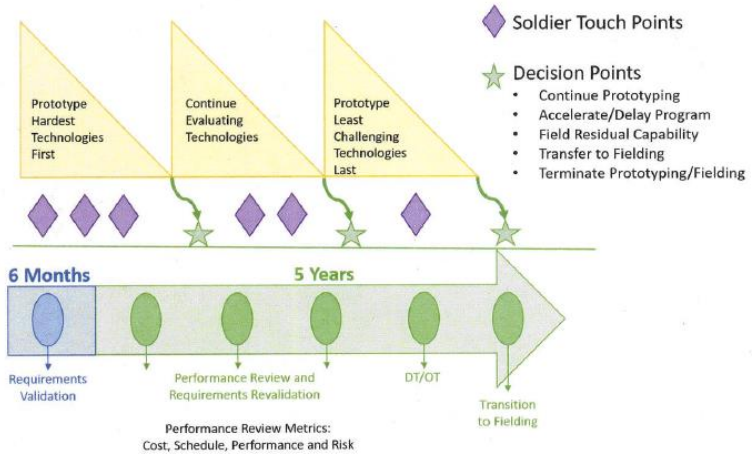


Figure 5. Middle Tier Acquisition Notional Prototyping Timeline. Jette, B. D. (2018, September 25). Office of the Assistant Secretary of the Army (Acquisition, Logistics, Training) Middle-Tier Acquisition Policy [Letter to Army Distribution]. 103 Army Pentagon, Washington, DC.

The memorandum also includes a summary table describing the purpose and objectives of rapid prototyping and rapid fielding directly from the 2016 NDAA as seen in Table 1.

Table 1.
Summary of NDAA 2016, Section 804 Statutory Language

	Rapid Prototyping	Rapid Fielding
Purpose	Provide for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs	Provide for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required.
Objective	Field a prototype that can be demonstrated in an operational environment and provide for a residual operational capability within five years of the development of an approved requirement.	Begin production within six months and complete fielding within five years of the development of an approved requirement.
Starts with	A merit-based process for the consideration of innovative technologies and new capabilities to meet needs communicated by the Joint Chiefs of Staff and the combatant commanders.	A merit-based process for the consideration of existing products and proven technologies to meet needs communicated by the Joint Chiefs of Staff and the combatant commanders
Includes	▪ Developing and implementing acquisition and funding strategies ▪ Process for demonstrating and evaluating the performance of fieldable prototypes developed pursuant to the program in an operational environment ▪ Transitioning successful prototypes to new or existing acquisition programs for production and fielding under the rapid fielding pathway or the traditional acquisition system	▪ Demonstrating performance and evaluating for current operational purposes the proposed products and technologies ▪ Developing and implementing acquisition and funding strategies for the program ▪ Considering lifecycle costs and addressing issues of logistics support and system interoperability ▪ Opportunities to reduce total ownership costs
Not subject to the Joint Capabilities Integration and Development System Manual and Department of Defense Directive 5000.01, except to the extent specifically provided in guidance		
Term "major defense acquisition program" does not include an acquisition program or project that is carried out using the rapid fielding or rapid prototyping acquisition pathway (FY18 NDAA Sec 831)		

Note. Excerpt from memorandum, Jette, B. D. (2018, September 25).

With the Air Force and Navy providing very similar memorandum guidance, the U.S. military services are clearly on board with the MTA strategy. The services are actively promoting MTA use through detailed policy with the goal of successfully implementing rapid prototyping and rapid fielding.

Given the current acquisition environment and Army modernization priorities, it is not surprising that during the literature review of relevant topics, a recurring theme of speed and risk taking appeared. On October 12, 2017, then Secretary of Defense, James Mattis, penned a letter to

DoD personnel echoing the top three lines of effort described in the current National Defense Strategy objectives that include the need for lethality, stronger alliances, and the need to bring business reform to the DoD. Regarding this third priority, he stated that "This line of effort instills budget discipline and effective resource management, develops a culture of rapid and meaningful innovation, streamlines requirements and acquisition processes, and promotes responsible risk taking and personal initiative" (Pellerin, 2017, p. 2). He emphasized the need to "use your force of personality to lead with a sense of urgency and purpose every day" (Pellerin, 2017, p. 2). Without the oversight found in a traditional program, the application of Middle Tier acquisition via rapid prototyping and rapid fielding will require the services, Program Executive Officers (PEOs), and PMs to accept greater personal and programmatic risk as they make decisions at increasingly lower levels. This is ironic in terms of this analysis in that prototyping is generally considered to be a risk reduction activity.

Application of Technology Demonstration and Prototyping

A significant amount of research has looked at prototyping over the years, and some of those results have driven legislation that not only requires prototyping but requires competitive prototyping. Although much of the research conclusions are generally qualitative in nature, some quantitative data provides historical insight regarding how programs have chosen to use or not use TD&P as part of their acquisition strategy. Although a large number of multi-dimensional variables regarding the benefits or cost of prototyping make quantative analysis problematic, the data from past programs has enabled researchers to make generalized observations using actual program schedules, and cost. The performance aspect is somewhat more difficult to quantify, so

many of the researched quality assessments came from program manager survey data and general interpretation of outcomes of programs that did or did not prototype. The literature review has focused on the why, when, and how aspects of prototyping and rapid fielding to better understand its effective application in today's environment. The NDAA Section 804 statutory language requires prototyping and wisely gives broad guidance in terms of purpose, objectives and broad implementation guidance enabling program managers significant flexibility. To provide the acquisition professional a broader understanding of TD&P the analysis and findings of this paper specifically delve into the nature and role of prototyping in terms of:

- Goals, timing, and integration
- Developing a prototyping strategy by knowing what questions to ask
- Use of competitive prototyping and the variables to consider
- Managing the cost, benefits, and overall value
- Effects of technology and emerging threat
- Other Transaction Authority (OTA) application

Goals, Timing, and Integration

Understanding the purpose, that technology demonstration and prototyping serve, is critical to reaping the maximum benefit from these activities. Specifically, program managers must "identify their goals, focus areas, scope, approaches, funding characteristics, strategies, coordination mechanisms, and barriers, if any, they face" (United States Government Accountability Office, 2017, p. 3). So what are the reasons for prototyping? "Prototyping is widely believed to reduce cost and time; allow demonstration of novel system concepts; provide a

basis for competition; validate cost estimates, design, and manufacturing processes; and reduce or mitigate technical risk" (Drezner & Huang, 2010, p. 3). In an environment of risk and uncertainty, prototypes can add value by improving insight into the proposed material solution thereby improving the quality of programmatic decisions. The 2017 GAO report on weapon systems asked program managers from 17 programs that prototyped out of the 22 programs reviewed and found that "the programs we reviewed used prototyping primarily to reduce technical risks, investigate integration challenges, validate designs, and mature technologies" (United States Government Accountability Office, 2017, p. 9) as depicted in Figure 6. Further noting that: "program officials stated that they tailored their prototyping approaches to their program's risks, with riskier programs prototyping more extensively" (United States Government Accountability Office, 2017, p. 9). Program managers that assessed their programs as lower risk with more mature technology prototyped subsystems or did not prototype at all.

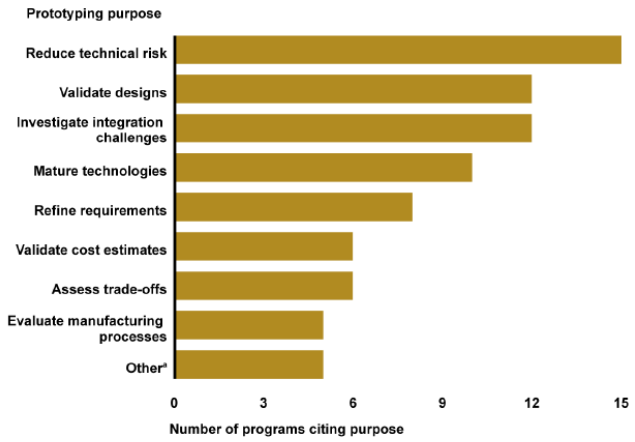


Figure 6. Why Do Major Defense Acquisition Programs Prototype? Rep. No. Report to Congressional Committees-GAO-17-309 at 9 (2017). United States Government Accountability Office

Application of Technology Demonstrations and Prototyping in Middle Tier Acquisitions

Technology demonstration and prototyping occur for a variety of reasons. Figure 7 depicts the types and timeframes generally used for varying purposes. Note that conceptual, developmental, and operational prototyping generally align with the NDAA Middle Tier aspects of technology demonstration, rapid prototyping, and rapid fielding.

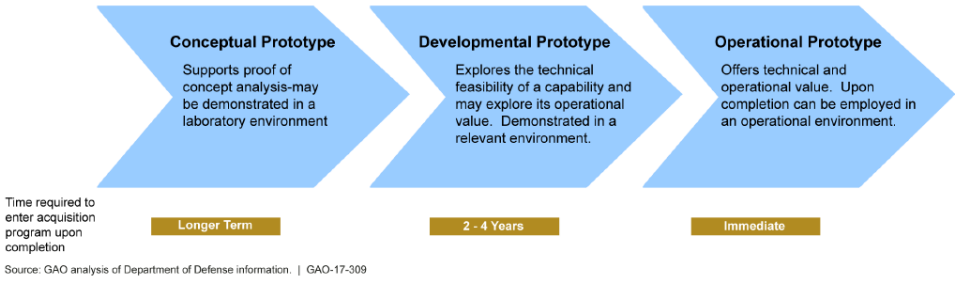
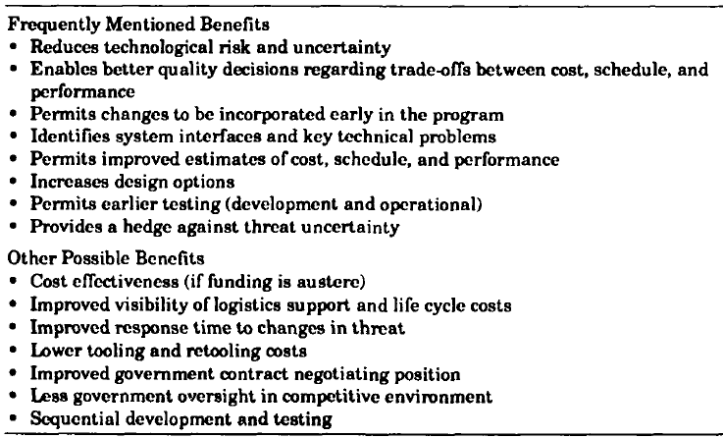


Figure 7. Prototyping Types and Time Horizons. Rep. No. Report to Congressional Committees-GAO-17-309 at 6 (2017). United States Government Accountability Office

To better manage prototyping activities, the new emerging capability and prototyping office is separating prototyping activities into two categories. Operational prototyping activities will closely replicate previous rapid fielding activities performed by the office. Operational prototypes can be expected to operate in the field for short periods and will incorporate form, fit and function into their design. Several of the system support considerations will also be assessed to help determine what aspects of the prototype will need to be matured for a follow-on program of record. The second category, developmental prototyping, affords an opportunity to explore the operational and technical value of less mature weapon systems with the focus more on the prototype's ability to

achieve useful military effects. Developmental prototyping allows for exploration of high-risk, potentially game-changing designs. (Hencke, 2014, p. 13)

Drezner (1992) offers a more detailed description as shown in Figure 8 that goes beyond the reasons for prototyping and addresses how information gained can be used.



Frequently Mentioned Benefits

- Reduces technological risk and uncertainty
- Enables better quality decisions regarding trade-offs between cost, schedule, and performance
- Permits changes to be incorporated early in the program
- Identifies system interfaces and key technical problems
- Permits improved estimates of cost, schedule, and performance
- Increases design options
- Permits earlier testing (development and operational)
- Provides a hedge against threat uncertainty

Other Possible Benefits

- Cost effectiveness (if funding is austere)
- Improved visibility of logistics support and life cycle costs
- Improved response time to changes in threat
- Lower tooling and retooling costs
- Improved government contract negotiating position
- Less government oversight in competitive environment
- Sequential development and testing

Figure 8. Perceived Benefits and Use of Prototyping. Drezner, J. A. (1992). The Nature and Role of Prototyping in Weapon System Development (p. 8, Tech. No. R-4161-ACQ). Santa Monica, CA: Rand

Figure 9 below presents a hierarchical taxonomy of goals.

The first level concerns the overall purpose of prototyping in the program; the second, the specific objectives of particular prototypes. In decreasing order of detail, these two levels relate to the kind of information that prototyping generates, and together constitute what we refer to as the goals of a prototyping strategy. (Drezner, 1992, p. 12).

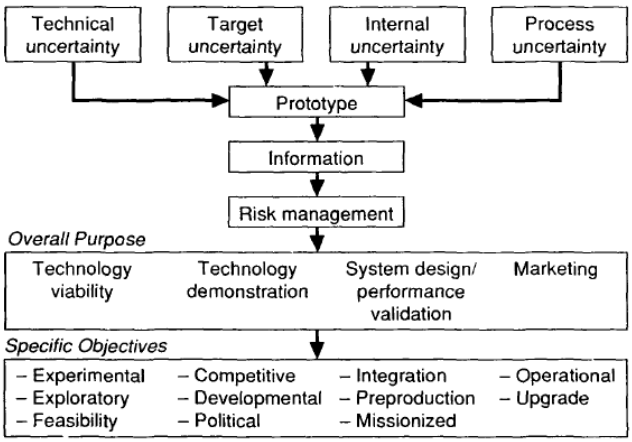


Figure 9. Prototyping Taxonomy. Drezner, J. A. (1992). The Nature and Role of Prototyping in Weapon System Development (p. 13, Tech. No. R-4161-ACQ). Santa Monica, CA: Rand

Timing and levels of integration are clearly tied to the goals. Specifically:

> Timing means the phase in which prototyping occurs, and it is related to the level of system or technological maturity. The level of system integration means the extent to which the prototype represents a production unit in scope and scale, and includes all necessary subsystems for operational deployment. (Drezner, 1992, p. 12)

Prototyping Strategy

Clear understanding of goals, integration, and timing are critical as DoD seeks to achieve the previously described benefits of technology demonstration and prototyping. The 2017 GAO report on weapon systems notes that although:

> DoD has developed new initiatives that are outside of major defense acquisition programs to increase prototyping and further innovation. DoD does not have a department-wide strategy that communicates strategic goals and priorities and

> delineates roles and responsibilities to guide the prototyping initiatives. (United States Government Accountability Office, 2017, p. 1)

The report goes on to state that "With DoD's increased level of effort and investment in prototyping and innovation comes the potential for inefficiencies if efforts are not coordinated and aligned with an overarching strategy" (United States Government Accountability Office, 2017, p. 29).

Regarding the current Middle Tier environment and the need for speed, it is interesting to note that the GAO report states:

> Developing an innovation strategy and ensuring adequate funding to support it, could also help foster a more risk tolerant environment. DoD's Defense Innovation Board is also in the process of identifying ways to develop a culture of innovation in DoD in which new ideas can be tested and fail without fear of ending or derailing the career of a science and technology manager, acquisition professional, or military officer. (United States Government Accountability Office, 2017, p. 34)

These observations are part of the impetus for this research as an information source in lieu of an overarching strategy. The literature review reveals several general assessments and guidance on prototype strategy development and implementation that could guide programs to rapidly prototype and field new capabilities. A Rand report cautions there are no "generic strategies that can be applied to defined circumstances. Each program is unique. "While

classification schemes are useful, an effective prototyping strategy must be tailored to reflect this real-world variation" (Drezner, 1992, p. 20).

Given the wide variations in prototyping strategies, it is helpful to break down a specific strategy in terms of determining what, how, when, or if prototyping is appropriate. Risk reduction is the primary purpose of TD&P with timing, technology maturity, quantity, competition, and levels of fidelity being the primary variables that drive strategy. "Partial system prototyping appears to be more often associated with technology demonstration purposes and occurs earlier in a program, while full systems are more often associated with system design purposes and occur during full scale development" (Drezner, 1992, p. 48). Various weapon types tend to lend themselves to different strategies in terms of main purpose, management style, agency preference, development phase, quantity, and the level of integration of components, subsystems, or system design prototypes. Given these complexities and wide variance in weapon system development, the literature review provides general observations, guidance, and criteria that will potentially enable program managers to develop unique and effective TD&P strategies particular to their program.

The report on *Prototyping Defense Systems* prepared for OSD provides general observations and recommendations for what and how to prototype as summarized in Table 2 below:

Table 2.
Summary of General Prototyping Observations and Recommendations

- Austere early research and development through technology demonstration
- Concurrent developments of critical subsystems help reduce risk
- Early testing with user involvement and feedback to designers
- Early prototyping vice paper designs provides insight to functionality and ease of integration
- What Kinds of Systems: - New performance or manufacturing technology for the contractor - High cost per unity and high quantity - Long lead time or high cost to correct potentially unforseen problems
- How to Prototype: - Generally the earlier the better - Concept demonstration for all new systems - Operational suitability especially in funding or schedule crunch - If risk is largely schedule/technical then concept and design prototyping is most important - If requirements uncertainty then operational suitability is important - Cost or producibility the add mission demonstration - Add competition if technical risk is high

Note. Adapted from (Tyson, Nelson, Gogerty, Harmon, & Salerno, 1991, pp. 19, 37)

The 2017 GAO report on Weapon Systems provides the following summary recommendations on strategies for prototype implementation on Table 3 below:

Table 3.
Summary of GAO Prototyping Observations and Recommendations

- **Identify risks early and target prototyping efforts to address them**. Focus prototyping efforts on maturing critical technologies and demonstrating them in a relevant environment.
- **Structure prototyping efforts to be completed in time to inform key decisions, particularly source selection**.
-**Specify the level of fidelity needed to provide the necessary information about which risks to address**. For example use of high fidelity prototyping to make trade-offs vice demonstrating a feasibility.
- **Ensure the appropriate level of insight into the design and cost information**. The level of insight can be affected by factors, such as the type of information a program requires a contractor to provide under a prototyping contract. The data can be used to mature its cost estimate and possibly use a firm fixed price contract for system development.
- **Keep plans flexible to adapt to information learned during the effort**. Use multi-phased prototyping approaches and a few described adding or removing contractors. Be prepared to change strategies or modifiy the approach based on information learned or in response to a tighter budget environment.

Note. Adapted from GAO. (2017). Weapon Systems (p. 17, Tech. No. GAO-17-309)

The 2010 Lessons from Rand Research *On Prototyping* provides some historical observations and suggestions, as summarized in Table 4, for some of the conditions under which prototyping strategies are most likely to yield benefits in a development program. The report goes

on to state that although the available evidence is somewhat mixed overall, the historical record does suggest successful application of prototyping strategies in the future requires either creating these conditions or ensuring that they exist to the extent possible.

Table 4.
Conditions That Favor Prototyping

- **Results Are Used to Inform Key Program Decisions.** If early testing of a prototype indicates that available technology is not yet mature enough to confidently predict that system performance requirements will be met, then pushing ahead in that program without easing requirements and performance expectations to match technologic maturity will result in significant cost growth, schedule slip, and performance shortfalls.
- **The Prototype Is Designed to Demonstrate the Critical Attributes of the Final Product in a Realistic Environment.** Prototyping strategies appear to yield benefits when they are focused on specific challenges or designed to generate specific kinds of information to inform specific kinds of decisions.
- **Prototyping Strategies and Documentation Are Austere.** There is some evidence, particularly from the many past aircraft prototypes, that an austere program is an important attribute of a successful application of prototyping. Prototyping should include only the minimum necessary requirements with minimum documentation to analyze test results and lessons learned for maximum flexibility to make the inevitable cost–performance trade-offs.
There Should Be No Commitment to Production During the Prototyping Phase. Prototyping is experimental in nature, and failure is a possible outcome in the sense that the desired capabilities could not adequately be demonstrated in a realistic environment and at a reasonable cost. Such an outcome would be strong evidence that the requirements need to be relaxed and additional technology development and maturation is needed.
No Additional Requirements Are Added or Performance Increases Expected. Changing the design to add capabilities that were not part of the initial design concept and therefore not explored during prototyping may limit the value of the information gained during prototyping. Again, this condition relates to the need for an austere, focused prototyping effort used to inform specific decisions regarding design, requirements, and technology.

Note. Adapted from (Drezner & Huang, 2010, pp. 18-20)

The *Prototyping Defense Systems* report goes on to provide suggestions summarized in Table 5 on how much is worth investing in prototypes with the understanding that more analysis is needed to refine these guidelines.

Table 5.
How Much is itWorth Investing?

- **Prototyping is a leveraged investment** – spend small dollars to avoid large surprises
- **Prototyping cost should probably be less thatn the highest estimate of:** - 25% of EMD cost estimate - 10% of acquisition cost estimate (EMD and Procurement) - 5% of life cycle cost estimate
- **Prototyping costs can be captured and used to refine EMD and procurement cost estimates**

Note. Adapted from (Tyson, Nelson, Gogerty, Harmon, & Salerno, 1991, p. 38)

Finally, the *Prototyping Defense Systems* document identifies detractors of prototyping and suggests reasons why prototyping should not be undertaken as summarized in Table 6. below:

Table 6.
Reasons to Not Prototype

- **Takes too long.** Decision makers may view the prptotype phase as added on to the schedule without a prototype even though it may save time in EMD and solve technical problems early.
- **Costs too much.** Analogously with schedule, detractors regard the up-front cost of prototyping to be an obstacle.
- **Slows momentum of the program.** Some argue that a pre-EMD prototype loses technical momentum and getting to initial operational capability will take additional time.
- **Delays funding commitment.** Along with momentum, major funding commitments tend to be delayed while prototypes are built and tested.
- **Quantitative benefit not documented.** The literary evidence on prototyping consists mainly of case studies and qualitative observations.

Note. Adapted from (Tyson, Nelson, Gogerty, Harmon, & Salerno, 1991, pp. 14-15)

Competitive Prototyping

The use of competitive prototypes can sometimes enhance efficiency during acquisition. Competition among industrial suppliers is a common practice during the design phase when costs are small.

> Although the front-end costs of such an approach are quite apparent (the full cost of the second, unsuccessful competitor), the benefits lie mainly in subjective arguments that competition makes each firm work more productively, increasing the quality or reducing the overall cost of the final product. (Smith, Barbour, McNaugher, Rich, & Stanley, 1981, p. 7)

On May 22, 2009, the President signed into law the Weapon System Acquisition Reform Act of 2009 (WSARA). An important feature of WSARA is the requirement for all Major Defense Acquisition Programs (MDAPs) to conduct competitive prototyping (CP) prior to the Milestone B development decision.

> However, if the MDA determines that there is little or no benefit competitive prototyping can be waived. (Fast, 2016, p. 1)

As such, "A mandate for competitive prototyping has periodically been included in revisions to the DoD 5000 series of regulations governing the defense acquisition system" (Drezner & Huang, 2010, p. 3). Middle Tier acquisition legislation does not fall within the mandate of the DoD 5000 series, Given the perceived value of competitive prototyping, the Office of Management and Budget identifies competitive prototyping as a risk mitigation tool and cites five advantages for its use as compiled in Table 7.

Table 7.
Prototyping Advantages

- Proves concepts are sound.
- Allows efficient and effective communication (among operational users, procurement agency, and commercial contractors) to identify the best fit between agency (operational user) needs and marketplace capabilities.
- Provides for competition during the development effort.
- Where appropriate, ensures development remains constrained.
- Facilitates firm fixed-price contracting for production".

Note. Adapted from (Mitre Corporation, 2018, p. 2)

The RAND study had mixed results suggesting other factors such as requirements creep, budget instability and technical maturity might have more impact on program success as opposed to the positive or negative impacts of competitive prototyping. "For example, it is unlikely that substantial insight into contractor manufacturing processes to be used later for full-scale production will result from a prototyping effort unless considerable funding is devoted to tooling up for the prototype activity" (Mitre Corporation, 2018, p. 2). Given the complexities of deciding

on whether to prototype competitively, the Mitre Corporation has published competitive prototyping guidelines to assist in this decision process as summarized in Table 8 below:

Table 8.
Competitive Prototyping Guidelines

- **When size (and skill) matters**: Acquisition program offices that employ CPs successfully tend to require a larger contingent of government systems engineers with greater than average technical competence.
- **Right-sizing CP requirements**: CP is an investment that buys information to reduce uncertainty and risk. However, CP adds up-front costs to a program right at a time when funding may be scarce and support for the program is often weak. They must focus on areas that have substantial risk or offer a high reward-risk ratio.
- **Make sure your CP learns from antecedent activities**: Some agencies are strongly recommending or mandating prototyping in advance of technology development. Results of these prototypes shape and inform CP activities.
- **Have your CP do double duty**: The primary purpose of CP is to illuminate and eliminate technology maturity risks. But don't lose sight of the fact that a CP can give important insight into other risk areas such as contractor manufacturing processes and undiscovered operational user requirements.
- **Ensure persistent, active engagement of all stakeholders**: Structure CP efforts to encourage active participation of end users and other stakeholders throughout the CP life cycle. To facilitate that involvement, CP efforts should emphasize frequent demonstrations of progress and evidence that a prototype can scale.
- **Remember those without "skin in the game"**: Consideration of important stakeholders in the eventual outcome of a program, like certification and accreditation authorities, is key. Identify and bring these stakeholders into CP planning early so they can advise on “non-starters”, and be engaged through the entire process.
- **Commercial competitors are stakeholders too**: Commercial industry views CPs as investments. To attract the best commercial competitors for your program, Clear definition of CP goals and any basis for industry investment (e.g., internal research and development) must be convincing. In particular, the production potential of the contract must be visible and attractive to would-be competitors.
- **Don't stop competition too quickly**: Make sure there is sufficient information to make informed decisions before terminating a competition.
- **Beware the Potemkin Village (an attempt to deceive others into thinking that a situation is better than it really is)**: Ensure each competitor is presenting an actual prototype and not simply performing a scripted demonstration. Prototype operation should proceed without a script and by a domain expert.
- **Keep your eyes on the prize**: Carefully evaluate the potential risks of a prototype's becoming the actual product. Prototypes often do not have robust architectures, a full set of requirements, or complete documentation. These weaknesses may become deployment risks, such as lack of maintainability, scalability, or reproducibility.

Note. Adapted from (Mitre Corporation, 2018, pp. 7-9)

Last, the lack of definitive evidence supporting the benefits of prototyping in general and competitive prototyping in particular, is somewhat troubling. Existing case studies and statistical analyses present the policymaker with mixed results. As a result, DoD’s new competitive prototyping mandate was incorporated into policy without a strong link between the new policy emphasis and its intended

> improvement to program cost, schedule, and performance outcomes. Does competitive prototyping really result in better outcomes? Under what conditions will competitive prototyping yield the desired benefits? What are the key lessons from past and more recent experience with competitive prototyping? How can the potential benefits of competitive prototyping be maintained in the face of all the other factors affecting program outcomes? (Drezner & Huang, 2010, p. 22)

Cost, Benefits, and Overall Value

The Middle Tier rapid prototyping and rapid fielding initiative have a basis in the concept of prototyping. Assessing the value of this approach is difficult given that both costs and benefits are multidimensional.

> There are several ways in which costs can (and should) be considered. The obvious is in terms of dollars, both the actual expenditure involved in the prototyping activities and as the percentage of total program acquisition costs. But there are additional costs to be considered. Time is a form of cost, for example, though it may not be measured in dollars. There are political costs as well. For instance, taking the time to demonstrate technology might give opponents of a program time to gather support to terminate or restructure it. Similarly, a prototyping activity that demonstrates that a technology is not mature enough to be incorporated in a new system might also provide a basis for increased political opposition to the entire project, even if the relative level of technological advance

> of the system was reduced as a result of information gained through prototyping. (Drezner, 1992, p. 70)
>
> Benefits are perhaps even more difficult. For instance, benefits may be thought of as a reduction in development risks. But we cannot quantify how much risk is reduced. Nor can we know exactly what kinds of risks are reduced for each type of prototyping activity. There are other benefits to prototyping as well, such as the possibility that more accurate cost, schedule, and performance estimates will allow better-quality decisions regarding cost, schedule, and performance trade-offs, and increase design options. (Drezner, 1992, p. 71)

The report on *Prototyping Defense Systems* suggests that prototyping generates both qualitative and quantitative information. Qualitative in the sense of assessing the functionality of a design's performance characteristics. Also programmatic information, such as whether contractor teams mesh well and with competing teams who have the best design approach. Quantitative information includes performance, schedule, and cost dimensions. Acquisition managers can gain insight into how long a program will take and how much the program will likely cost. Benefits cannot be evaluated in a quantitative fashion. Although cost and schedule are measurable to a certain degree, the qualitative benefits are by definition not measurable since performance has different dimensions across equipment types (Tyson, Nelson, Gogerty, Harmon, & Salerno, 1991).

> We cannot be confident that we can identify all possible benefits and costs. Benefits and cost are measured on a different scale, if they can be measured at all,

> and we do not know how to reconcile those scales consistently across all the dimensions of costs and benefits. Even if we could measure all relevant costs and benefits, we cannot consistently weigh them in a decision process. Differences in program characteristics (e.g., technological difficulty and maturity, cost and schedule constraints, the level of uncertainty regarding the technology's military utility, etc.) suggest that those weights will differ greatly across programs and also as a function of the goals and activities involved in a particular prototyping application. (Drezner, 1992, p. 71)

In summary, the research indicates that there are generally positive benefits to prototyping by helping to uncover surprises and mitigate cost and schedule issues by garnering a deeper technical understanding of the proposed system early in the development phase. Although prototyping is no panacea, it does support insight into cost and schedule baselines and provides the opportunity to buy early information relatively cheap as opposed to learning about costly design changes needed later in the program. Everything is a tradeoff, and program priorities will drive prototyping decisions. Integration of mature technologies into a system will enable rapid prototyping and rapid fielding. Use of mature technologies can generate quick wins for urgent and emergent needs with residual capability. Technology development demonstrators or prototypes push the art of the possible, but they take longer and cost more. Significant differences in the application of mature or immature technologies indicate that competition is beneficial. If the goal is to develop technology and learn through prototyping, then there are obvious cost and schedule

implications. System complexity, operational needs, technology maturity, cost, and funding streams are the big drivers for trading in support of prototyping decisions.

Technology and Emerging Threat

Without the impediments of a bureaucratic weapon system development and acquisition process, many U.S. adversaries are able to make use of off-the-shelf, low cost, current technology such as GPS and unmanned aerial vehicles to rapidly modify and field weapon systems. Easy access to information through the Internet coupled with a global economy filled with readily available products is driving the need for the U.S. to relook our acquisition strategies.

> Capability development cycles, traditionally measured in years and decades, will need to be measured in months if they are to outpace our adversaries. Rapid prototyping technologies and techniques are well positioned to support the need for reduced development cycle times. A well-outfitted rapid prototyping lab contains all that is needed to produce new products in days to weeks (rather than in months to years). Computer Aided Design and Manufacturing software linked to Computer Numerically Controlled (CNC) machines quickly mill, cut, and build up material components. Combined with Field Programmable Gate Array integrated circuits, these tools allow prototyping labs to quickly build up and rapidly modify complicated new prototypes. (Hencke, 2014, p. 13)

Furthermore, three dimensional printing, also known as additive manufacturing, technology has improved significantly over the past several years with the ability to produce high quality, low cost, and functional prototypes in a variety of plastic and metallic materials.

> DoD prototyping also occurs outside or independent of acquisition programs. One of the purposes of this type of prototyping can be to further disruptive innovation. Disruptive innovation attempts to shift the balance of military power in our favor by providing new capabilities, potentially unforeseen by the warfighter. The capabilities can be a result of new technologies, new ways to integrate existing technologies, or changes to how systems are employed. (United States Government Accountability Office, 2017, p. 8)

Examples of potentially disruptive technologies include directed energy, low cost satellite constellations, hypersonic weapons, autonomous robotics, augmented reality devices, etc. Technology demonstration and prototyping are critical to the development of disruptive technologies as a risk reduction activity based on the low level of technology readiness associated with these new systems. Not every disruptive technology development effort will result in systems with military utility. The GAO proposes the notional model shown in Figure 10.

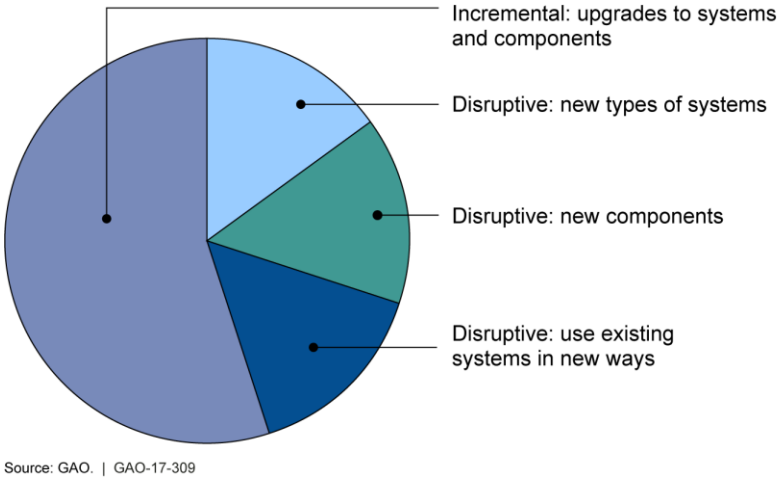


Figure 10. Model for Application of Disruptive Technologies. Rep. No. Report to Congressional Committees-GAO-17-309 at 30 (2017). United States Government Accountability Office

The application of developmental and operational prototyping along with rapid fielding of mature and or disruptive technologies will certainly affect our ability to respond to an emerging threat environment at a greater pace of innovation. Given the propensity for speed and the pace of technology growth, this type of high risk high reward approach may have a greater place within future DoD acquisition.

Other Transaction Authority (OTA)s Application

> The 1994 congressional authorization to use OT for prototype projects is potentially one of the most powerful reforms to the acquisition process in a long time. In one action, it swept away several decades' accumulation of laws and procedures that constrained managers in how they designed and managed such projects as well as how the government-industry relationship was defined. (Smith et al., 2002, p. 5)
>
> OT agreements are different from conventional contracts in several important ways. One is that they are relatively short and clearly written without use of specialized legal language. But probably the most important fundamental difference is that each and every clause in an agreement represents a negotiated position tailored to the needs of all parties. The essence of an OT agreement is that there are no rigid rules that must be applied, which opens an enormous range of opportunities for innovative strategies and processes. (Smith et al., 2002, p. 12)

In January of 2017, the Department of Defense published an Other Transaction Guide for Prototype Projects.

> The purpose of this guide is to assist Agreements Officers in the negotiation and administration of OTs (also referred to herein as "OT agreements" and "agreements") for prototype projects. It is also meant to aid DoD personnel who are interested in understanding OTs and discerning their usefulness in broadening DoD's ability to access commercial and cutting edge technology from companies or individuals which are unable or unwilling to enter into procurement contracts. (Department of Defense, 2017, p. 1)

"It is undeniable that the relaxation of financial and other controls inherent in the OT process opens some opportunity for abuse. However, the process also strengthens the access and information available to government managers, thus reducing such risks" (Smith et al., 2002, p. 32). Given the flexibility of this contracting tool and current leadership endorsement of its use, the OTA is becoming an integral part of the Middle Tier acquisition process.

Conclusions & Recommendations

Conclusions

This paper seeks to better understand the use of Middle Tier acquisition policy, technology demonstrations, and prototyping to address the research question with emphasis on determining the programmatic value of these tools in terms of cost, schedule, and performance. The Middle Tier and Other Transaction Authorities have loosened many of the traditional

acquisition requirements and may have a positive impact in terms of cost and schedule. Rapid prototyping and rapid fielding will enhance the performance aspect in terms of fleshing out technical maturity and military utility of fielded prototype systems. These benefits do however come with the potential for greater programmatic risk evaluated and managed at lower and lower levels within the acquisition community. Determining and or quantifying the overall cost and benefits of rapid acquisition and prototyping is difficult given the varying units of measure such as dollars, time, effectiveness, lethality, risk, utility, political implications, etc. Unfortunately varying prototyping strategies, program-specific characteristics, and the current acquisition environment do not support any directly applicable and or specific rules or criteria regarding when, if, or how to prototype. There is no single generic approach to prototyping that could be considered universally applicable. This research has been able to conclude that having a general understanding of the overall nature and role of prototyping will enable program managers to make informed decisions regarding their technical, political, and economic challenges in relation to their acquisition strategies. When used effectively, prototyping can help reduce risks and improve the likelihood that a program completes on time and budget. Presentations of specific conclusions are within a similar framework of the findings and analysis section of this paper.

- Goals, Timing, and Integration

A clear understanding of our ability to effectively establish Middle Tier programs that fully address the nature of programmatic goals and objectives should improve how we prototype and rapidly field weapon systems. Prototypes developed at the effective level of fidelity will have significant impact on our ability to deal with emerging threats. Arming our acquisition

professionals with the tools to rapidly field new, incremental, and disruptive technologies will clearly affect our posture in terms of national security. A combination of goals, timing, and level of integration appear to be the most common and significant factors in planning a rapid prototyping and rapid fielding effort.

- Developing a Prototyping Strategy by Knowing what Questions to Ask

Having historical references and general guidelines from a variety of sources for consideration in making strategy decisions should assist program managers in making prototype strategy decisions in the future. Drezner found that:

> The factors affecting the type of prototyping strategy chosen, and the effect of that strategy on program outcomes, are generally unknown. Comparison of prototyping and non-prototyping programs case studies, on the other hand, provides considerable detail regarding the role of prototyping in a few specific programs. Alone, this approach is unsatisfying in the sense that the results are not necessarily generally applicable; it is difficult to formulate general policy from a few case studies. However, case studies do allow identification of the factors affecting the type of prototyping strategy used and help us better understand the relative success of that strategy. (Drezner, 1992, p. 5)

- Use of Competitive Prototyping and the Variables to Consider

Generally lower cost, reduced risk, and improved quality are the primary benefits of competition. However, these benefits are not inevitable in every case given that a second source will require additional cost, time and programmatic effort. Specifically, some may argue that

competition may yield minimal benefits and possibly hurt the program if the competing vendors produce very similar products demonstrating similar utility. Wise use of competition will augment the cost, schedule, and performance aspects of future acquisitions.

- Managing the Cost, Benefits, and Overall Value

The value of prototyping is a measure of benefit versus cost. Benefits are multidimensional by their very nature and costs come in terms of dollars, time, and risk. Many acquisition professionals will find it frustrating that direct comparisons from past programs cannot be directly applied to decision tools for future use. The research indicates that prototyping and competitive prototyping generally increase initial cost and schedule early in a program's life cycle with the promise of balancing and or mitigating cost and schedule overruns later in a program's life cycle. Performance benefits are often affected by several factors independent of prototyping such as technical, contractual, funding, or political aspects that may overwhelm any benefits gained through prototyping. Qualitative assessments, rules of thumb, and general guidelines are the primary tools available to program managers as they move forward with rapid prototyping and rapid fielding initiatives. The effect of prototyping on program cost, schedule, and performance is ambiguous due to the variables involved with assessing courses of action in terms of the overall value. Understanding programmatic characteristics, contract type, requirements, number of prototypes, decision layers, and amount of documentation, will ultimately affect the success of Middle Tier acquisition.

- Effects of Technology and Emerging Threat

The rapidly evolving environment posed by near peer nations and the abilities of counterinsurgency threats to rapidly employ game changing technology on the battlefield is of significant concern as addressed in the U.S. National Security and National Defense Strategies. The application of Middle Tier rapid prototyping and rapid fielding initiatives is critical to our ability to meet and overcome these threats. Aggressive application of innovative program management and contractual tools is key to our future success in overcoming these clear and present dangers to our national security. Hencke found that:

> Perhaps most important, a concerted focus on prototyping activities directed toward developing those critical enablers to innovation—open architectures, modular and reusable designs, and the early application of a rapid, iterative development cycle methodology—can help the DoD build the portfolio of agile and flexible systems it needs to outpace any adversary. (Hencke, 2014, p. 14)

- Other Transaction Authority (OTA) Application

The NDAA Middle Tier policy and recent service guidance are clear indicators that speed is the current priority. Balancing the fiscal and technical challenges to enable rapid acquisition is the present challenge for program managers. This research concludes that prototyping is generally a value added approach especially when properly integrated as part of the OTA contracting vehicle. With flexibility being the heart of the OTA process, the balance of risk and reward in its application of rapid prototyping and rapid fielding will inevitably become more of the norm in future acquisition strategies.

Recommendations

Recommendation 1: Create and maintain a culture of empowered leadership minimizing micromanagement. Although this is a tall order, the culture needs to be one that truly manages and occasionally/frequently accepts selected risks to achieve the desired speed in acquisition. Senior leadership needs to delegate risk acceptance authority to lower levels in order for this to become a reality. Propagate an understanding that prototyping is intended to identify problems and that when this happens these issues do not necessarily indicate a programmatic failure. This approach appears to be in line with the vision of the Army's Futures Command, Mission Command philosophy, and the associated Cross Functional Teams that intend to operate with small and highly competent teams. Drezner found that "We recommend that prototyping be explicitly considered as part of the strategy for development of a weapon system, but that acquisition policy should reflect only broad guidelines on prototyping, rather than attempting to specify detailed prototyping strategies" (Drezner, 1992, p. 74).

Recommendation 2: Aggressively continue the path of Middle Tier acquisition in accordance with service guidance in terms of rapid prototyping and rapid fielding. Press forward to meet emerging warfighter needs in a timely fashion with a practical residual capability in order to "hedge against greater uncertainty in threats" (Drezner, 1992, p. 74).

Recommendation 3: Identify opportunities to work with the user community to identify new requirements ripe for the Middle Tier process as well as areas for incremental improvement of proven technologies in existing systems. Actively seek user engagement early in the program.

Recommendation 4: Assess and encourage the stable funding of Middle Tier acquisitions. Clarify how these activities will be funded other than via the existing RTD&E budgets of existing programs. Service guidance implies that separate Middle Tier funding lines will potentially be available in the future. Given the nature of the Program Objective Memorandum cycle, several years could pass before direct funding is available to support Middle Tier efforts.

Recommendation 5: Work with the Defense Acquisition University and industry to generate curriculum relating to Middle Tier acquisition. Share the innovative contracting methodologies available for use to promote a greater understanding amongst program managers of the effective application of technology demonstration and prototyping with respect to the NDAA legislation to enable a paradigm shift in thinking among acquisition professionals.

Recommendation 6: Work with the ASD (R&E)) office of Emerging Capability and Prototyping (EC&P) as well as the Joint Capability Technology Demonstration (JCTD) office to better understand prototyping models, processes, best practices, and lessons learned from past experiences. Continue to move forward with the Middle Tier process recognizing that the EC&P and the JCTD methods evolved from traditional acquisition and may require tailoring as rapid prototyping and rapid fielding enable new systems.

Recommendation 7: Generate an overarching DoD initiative for propagating and funding a department-wide strategy that communicates strategic goals and priorities and delineates roles and responsibilities to guide prototyping initiatives. This guidance should reduce inefficiencies and enable program managers in their efforts to implement Middle Tier policy. GAO found that:

> The recent increased level of effort and investment in prototyping and innovation comes with the potential for inefficiencies if efforts are not strategic and coordinated. Other high-risk investments in categories such as disruptive technologies may need to be protected from a risk averse culture, as well. (United States Government Accountability Office, 2017, p. 35)

Recommendation 8: Determine how programs initiated via the Middle Tier process will effectively transition to programs of record and address the concern of training and sustainment throughout the life cycle of the weapon system. The Army's Futures Command, Office of the Secretary of Defense, and the Army Materiel Command will be integral in this evolution.

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Acronyms

ACAT	Acquisition Category
AR	Army Regulation
AIS	Automated Information Systems
ASD(R&E)	Assistant Secretary of Defense for Research and Engineering
CP	Competitive Prototyping
DAE	Defense Acquisition Executive
DAU	Defense Acquisition University
DoD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
EC&P	Emerging Capability & Prototyping
FAR	Federal Acquisition Regulation
GAO	Government Accountability Office
JCIDS	Joint Capabilities Integration and Development
JCTD	Joint Capability Technology Demonstration
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Programs
MTA	Middle Tier Acquisition
NDS	National Defense Strategy

NDAA	National Defense Authorization Act (NDAA)
OTA	Other Transaction Authority
PEO	Program Executive Officer
PM	Program Manager
RDT&E	Research, Development, Test, and Evaluation
SSCF	Senior Service College Fellowship
TD&P	Technology Demonstration and Prototyping
TMMR	Technology Maturation and Risk Reduction
TRL	Technology Readiness Level
USD(ATL)	Undersecretary of Defense for Acquisition, Technology and Logistics
WSARA	Weapon System Acquisition Reform Act of 2009

Application of Technology Demonstrations and Prototyping in Middle Tier Acquisitions

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